

# **Report for 2002GU4B: Impact of Ordot Dump on Water Quality of Lonfit River Basin in Central Guam**

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**Report Follows:**

# PROJECT SYNOPSIS REPORT

## Project Title

Impact of Ordot Dump on Water Quality of Lonfit River Basin in Central Guam

## Problem and Research Objectives

Guam's only municipal solid waste disposal site is centrally located in the village of Ordot and has been in use for over fifty years. Lacking in the conventional technology built in to modern day sanitary landfills, the site is essentially an open dump covering ~20 acres of the upper Lonfit River valley. The dump was operated by the US Navy at the end of WWII and transferred to the Government of Guam shortly thereafter. Although slated for closure more than 20 years ago, it still receives around 200 tons of solid waste per day from the civilian community. Early records of the types of materials disposed of at the Ordot Dump are nonexistent but are suspected to include the same array of toxic chemicals found at other military dumpsites on island. Today, there is some control over the bulk disposal of industrial chemicals, waste oil, and metallic waste at Ordot Dump. However, household waste is rarely screened and is known to contain a variety of hazardous substances, both biological and chemical. Leachate streams occur in several places around the perimeter of the dump and course their way down gradient into the Lonfit River and out into Pago Bay. Their chemical composition is largely unknown and their impact on the local environment in terms of ecology, agriculture, and human health remains to be investigated.

The objectives of this project were to characterize the primary biological and chemical contaminants in leachate water emanating from the Ordot Dump and trace their respective movements down the watershed and out into the ocean. This was accomplished by examining surface water and soil interstitial waters at discrete locations between the dump and the coast to determine the distribution and abundance of primary contaminants and identify their differential mobilization rates in surface and subsurface environments.

## Methodology

Leachate samples were collected from two separate locations on the southern face of the dump and sent off-island for a one-time analysis of all priority pollutants listed under *Guam Water Quality Standards* (GEPA 2001). The high cost of this analysis precluded further testing.

Surface water samples were taken at monthly intervals from five sites along the Lonfit/Pago river systems between the dump and the ocean. These were analyzed for total coliforms and fecal indicator bacteria (*E. coli* and *Enterococci*), nutrients (NO<sub>x</sub>, NH<sub>4</sub>-N and orthophosphate-P) and heavy metals (Ag, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn). Samples for nutrient and heavy metal analyses were withdrawn directly into 50 ml polypropylene syringes and filtered through in-line 0.45 µm filters into 100-ml plastic vials.

Monthly subsurface water samples were taken from five sites around the western edge and southern toe of the dump. These were collected using suction cup lysimeters buried

to depths of 2, 4 and 6 feet below ground level. Samples were removed from the lysimeters under vacuum and analyzed for bacteria, nutrients and metals without further treatment.

All surface and subsurface water samples were stored on ice in the field. In the laboratory, those required for heavy metal analysis were acidified with analytical grade nitric acid (100 µl/100 ml). All bacteria and nutrient analyses were performed within 6 h and 24-h of collection respectively.

All bacteria counts were made using the Idexx Quantitray® technique. Total coliforms and *E. coli* were incubated at 35°C with Colilert® media to their respective color and fluorescent endpoints. *Enterococci* were incubated in Enterolert® at 41°C to a fluorescent endpoint.

Nutrient determinations were made using a multi-channel Flow Injection Analyzer (FIA) (Quickchem 800: Lachat Instruments). The analytical methods were those recommended by the manufacturer and are essentially the same as those described in *Standard Methods*, Part 4500 (APHA 1992) with modifications for flow injection analysis. The heavy metal analyses were carried out by conventional flame and flameless atomic absorption spectrometry.

### **Principal Findings and Significance**

#### *Leachate:*

The biological and chemical contaminants detected in the leachate samples are listed in Table 1 together with the appropriate surface water and safe drinking water quality standards for Guam. Especially noticeable are the extremely high counts of fecal indicator bacteria, which exceeded the Guam recreational water quality standards by at least three orders of magnitude. Presumably, these elevated numbers reflect unsanitary human wastes (e.g. disposable diapers) and animal carcasses placed in the dump as well as fecal contributions from the large populations of rodents, stray dogs and wild pigs in the area.

Of the 27 chemical contaminants detected in the leachate samples, 12 were found at levels that exceeded one or both of the water quality standards. Nutrient levels were particularly high, especially NH<sub>4</sub>-N. In fact, the pungent smell of ammonia was very noticeable at one of the leachate collection sites. Copper and Pb were also high in one of the samples compared with their respective surface water quality standard. Both metals are relatively toxic to aquatic organisms. Levels of all detectable metals were several orders of magnitude over and above those normally encountered in uncontaminated river waters (Denton *et al.* 1998).

It is interesting to note that relatively few organic solvents were found in the leachate and no pesticides other than p-dichlorobenzene. Likewise, no PCBs, PAHs, dioxins or furans were detected in either sample.

| Bacteria:                       | Units            | Results       | Guam Water Quality Standards |                    |
|---------------------------------|------------------|---------------|------------------------------|--------------------|
|                                 |                  |               | Surface Waters <sup>a</sup>  | Drinking Water     |
| <b><u>Bacteria:</u></b>         |                  |               |                              |                    |
| Total Coliforms                 | MPN Index/100 ml | 2,419,200     | -                            | 0                  |
| <i>E. coli</i>                  | MPN Index/100 ml | 137,400       | 126                          | 0                  |
| <i>Enterococci</i>              | MPN Index/100 ml | 298,100       | 33                           | 0                  |
| <b><u>Nutrients:</u></b>        |                  |               |                              |                    |
| NOx                             | µg/l             | 604           | 100-500 <sup>b</sup>         | 10, 1 <sup>c</sup> |
| NH <sub>4</sub> -N              | mg/l             | 503           | 3.08 <sup>d</sup>            | -                  |
| Ortho-P                         | µg/l             | 166           | 25-100                       | -                  |
| <b><u>Metals (total):</u></b>   |                  |               |                              |                    |
| Aluminium                       | µg/l             | 1600 - 4,500  | 1000                         | 50-200             |
| Antimony                        | µg/l             | 9.7           | -                            | 6                  |
| Arsenic                         | mg/l             | 0.007 - 0.046 | 0.15                         | 0.01               |
| Barium                          | µg/l             | 85 - 240      | -                            | 2000               |
| Boron                           | mg/l             | 1.6 - 5       | -                            | -                  |
| Chromium                        | mg/l             | 0.017 - 0.210 | 0.210 <sup>e, f</sup>        | 0.1                |
| Copper                          | mg/l             | 0.023 - 0.092 | 0.012 <sup>f</sup>           | 1.3                |
| Iron                            | mg/l             | 0.68 - 2.9    | 3.00                         | 0.3                |
| Lead                            | µg/l             | 4.7 - 45      | 3.20                         | 15                 |
| Manganese                       | µg/l             | 290 - 340     | -                            | 50                 |
| Nickel                          | mg/l             | 0.050 - 0.110 | 0.052 <sup>f</sup>           | 0.1                |
| Vanadium                        | µg/l             | 26 - 62       | -                            | -                  |
| Zinc                            | mg/l             | 0.083 - 21    | 0.11 <sup>f</sup>            | 5                  |
| <b><u>Pesticides:</u></b>       |                  |               |                              |                    |
| p-dichlorobenzene               | µg/l             | 3.4           | -                            | 75                 |
| <b><u>Organic Solvents:</u></b> |                  |               |                              |                    |
| Acetone                         | µg/l             | 17            | -                            | -                  |
| Benzene                         | µg/l             | 3.1           | -                            | 5                  |
| Ethylbenzene                    | µg/l             | 7.3           | -                            | 700                |
| Tetrahydrofuran                 | µg/l             | 10            | -                            | -                  |
| Toluene                         | µg/l             | 18            | -                            | 100                |
| cis-1,2-Dichloroethane          | µg/l             | 1.1           | -                            | 5                  |
| m,p-xylenes                     | µg/l             | 8             | -                            | -                  |
| o-Xylene                        | µg/l             | 3.6           | -                            | -                  |
| <b><u>Others:</u></b>           |                  |               |                              |                    |
| Cyanide                         | mg/l             | 0.007 - 0.016 | 0.0052                       | 0.2                |
| Phenolic Compounds              | mg/l             | 0.074 - 0.155 | -                            | -                  |

a = GWQS for freshwaters only; b = as nitrate nitrogen; c = as nitrate nitrogen and nitrite nitrogen respectively; d = Criteria Chronic Concentration (CCC) at pH 7.0  
e = CCC for Cr<sup>3+</sup> only; f = CCC estimated at total hardness of 100 mg/l; dashes indicate no standards currently available

**Table 1: Priority pollutants detected in leachate from Ordot Dump (Dec. '03)**

#### *Surface Waters:*

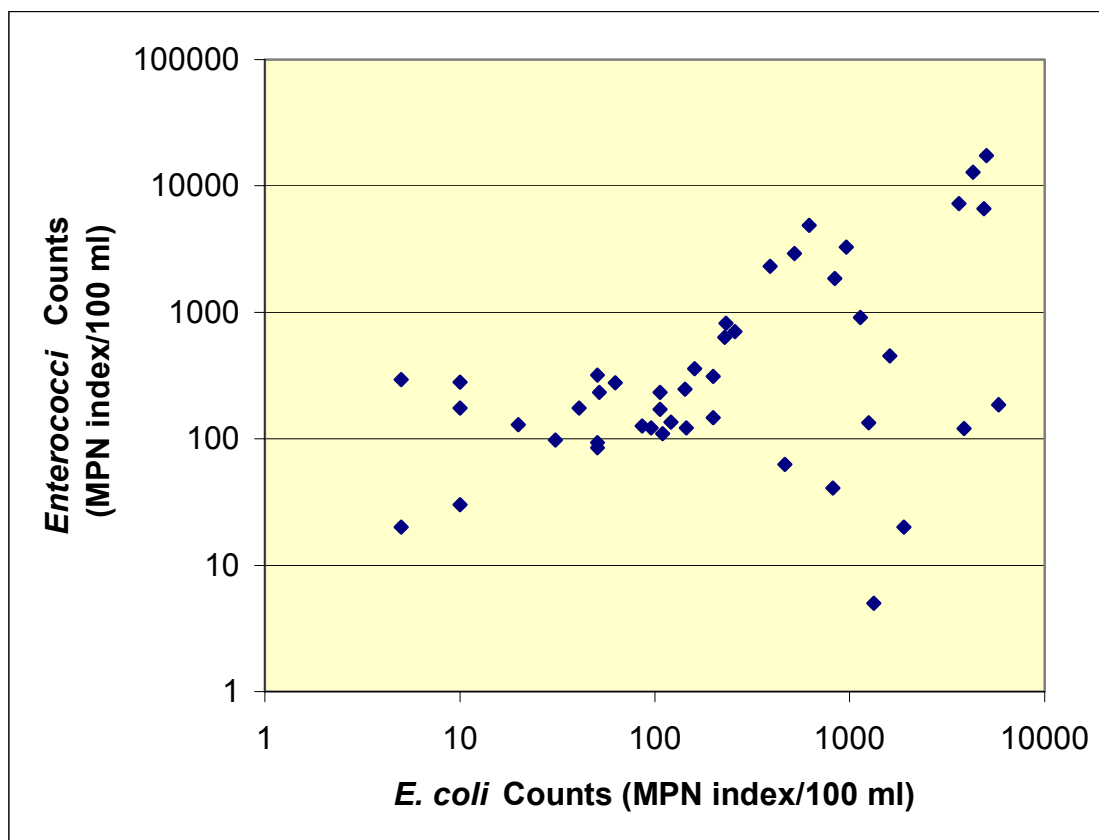
The results of the bacterial analysis of surface waters from the Pago-Lonfit River systems are shown in Table 2. As expected, counts for the fecal indicator bacteria, *E. coli* and *Enterococci*, were highest at site 1 near the point of convergence between the river and a major leachate stream. However, these quickly diminished within a few hundred meters downstream and, for *E. coli*, were mostly below the recreational water quality standard at sites 2 and 3. In contrast, the recreational water quality standard for *Enterococci* was exceeded at all sites almost all of the time.

| Station #       | Distance from Discharge Point (m) | MPN Index/100 ml                |                                |                                    |
|-----------------|-----------------------------------|---------------------------------|--------------------------------|------------------------------------|
|                 |                                   | Total Coliforms<br>mean (range) | <i>E. coli</i><br>mean (range) | <i>Enterococci</i><br>mean (range) |
| Leachate Stream | 0                                 | 2,419,200                       | 137,400                        | 298,100                            |
| 1               | 10                                | 38,820 (17,329 - 92,080)        | 1,553 (391 - 5,012)            | 4,661 (907 - 17,239)               |
| 2               | 500                               | 11,460 (4,352 - 24,192)         | 43 (5 - 259)                   | 146 (20 - 703)                     |
| 3               | 1,500                             | 1,189 (4,160 - 24,192)          | 59 (10 - 233)                  | 180 (30 - 816)                     |
| 4               | 4,500                             | 17,902 (8,050 - 24,810)         | 277 (51 - 1,609)               | 132 (5 - 631)                      |
| 5               | 5,000                             | 18,882 (5,850 - 26,130)         | 441 (20 - 5,794)               | 153 (20 - 1850)                    |

mean calculated as geometric mean

**Table 2: Bacteria in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)**

In general, fecal indicator bacterial counts were poorly correlated with one another both in space and time (Figure 1.). This suggests that they have very different survival times and reproductive capabilities in the environment.



**Figure 1: Relationship between *E. coli* and *Enterococci* counts in surface waters of the Lonfit-Pago River System (Oct. '02 – May '03)**

On occasions, relatively high fecal indicator bacteria counts were encountered at sites 4 and 5 in the lower reaches of the Pago River and likely reflect seepage from residential septic tanks in the Pago Bay area. There is also a small sewage treatment plant (aerated sludge system) nearby that services 15 or so houses and allows the effluent to percolate

into the ground (Ed Reyes, Guam Waterworks Authority, pers. com.). The data geometric means for both fecal indicators at these sites exceeded the Guam recreational water quality standards.

Nutrient enrichment attributable to runoff from the dump was only evident at site 1 and only for inorganic nitrogen (Table 3). Levels determined further downstream were reasonably typical of groundwater impacted streams on Guam (Denton *et al.* 1998) except at the coast (site 5) where unusually high levels of NO<sub>x</sub> and NH<sub>4</sub>-N were occasionally detected. Such findings again point towards the domestic wastewater inputs in the lower Pago basin area.

The absence of detectable levels of soluble inorganic phosphorus immediately downstream from the dump was unexpected considering the elevated concentration determined in leachate. Presumably, this nutrient is rapidly scavenged from the water column by iron as it changes oxidation state and precipitates out of solution as the hydrated ferric oxide.

| Site #   | Distance from Discharge Point (m) | Nutrients (µg/l)      |                    |                  |
|----------|-----------------------------------|-----------------------|--------------------|------------------|
|          |                                   | NO <sub>x</sub> -N    | Ammonia-N          | Orthophosphate-P |
|          |                                   | median (range)        | median (range)     | median (range)   |
| Leachate | 0                                 | 604                   | 503                | 166              |
| 1        | 10                                | 2,976 (1,350 - 3,380) | 42.2 (41.1 - 43.2) | all <1.0         |
| 2        | 500                               | 358 (229 - 487)       | 3.1 (1.3 - 6.3)    | all <1.0         |
| 3        | 1,500                             | 208 (111 - 305)       | 3.1 (1.7 - 5.2)    | all <1.0         |
| 4        | 4,500                             | 359 (151 - 567)       | <1 (<1 - 2.8)      | all <1.0         |
| 5        | 5,000                             | 1140 (130 - 10,000)   | 18 (1.4 - 24.5)    | all <1.0         |

**Table 3: Nutrients in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)**

Elevated heavy metal levels in the leachate stream were quickly diluted as they entered the Lonfit River at site 1 and were at normal baseline levels at all sites further downstream (Table 4). Iron and Mn were typically the most common elements detected and were generally followed in decreasing rank order of abundance by Cu>Zn>Pb>Cr and Ni. Levels of Cd, Hg and Ag were consistently below the limits of analytical detection at all sites so far examined.

In all probability, much of the soluble heavy metal load in the leachate stream rapidly partitions out onto suspended particulates upon entering the watershed and ultimately ends up in bottom sediments. These contaminated sediments would be gradually mobilized downstream and dumped in the Pago River estuary and adjacent waters.

It is suggested that sediment cores taken at strategic locations along the Pago-Lonfit River systems and out into Pago Bay would provide a more realistic measure of heavy metal distribution and abundance in this area. Such a sampling program would also provide a better understanding of the potential impact of these contaminants on the biota, particularly the suspension and deposit feeders and those organisms living in intimate contact with bottom deposits.

| Metal | Site # (distance from leachate stream) |                   |                   |                   |                  |
|-------|--|-------------------|-------------------|-------------------|------------------|
|       | Leachate (0 m)                         | 1 (10 m)          | 2 (500 m)         | 3 (1,500 m)       | 4 (4,500 m)      |
|       | mean (range)                           | mean (range)      | mean (range)      | mean (range)      | mean (range)     |
| Fe    | 1404 (680 - 2900)                      | 87.0 (12.0 - 646) | 16.8 (4.7 - 33.3) | 15.8 (3.8 - 27.8) | 14.9 (4.2 - 36)  |
| Mn    | 314 (290 - 340)                        | 272 (83.3 - 966)  | 21.5 (8.3 - 52.3) | 24.3 (7.3 - 73.8) | 27.4 (6.6 - 384) |
| Cu    | 46.0 (23.0 - 92.0)                     | 5.6 (1.7 - 31)    | 0.5 (0.2 - 2.0)   | 0.4 (0.2 - 1.4)   | 0.4 (0.2 - 2.2)  |
| Zn    | 1320 (83 - 21,000)                     | 2.8 (1.2 - 6.2)   | 0.1 (0.1 - 0.5)   | 0.1 (0.1 - 0.3)   | nc (<0.1 - 1.1)  |
| Pb    | 14.4 (4.7 - 45.0)                      | nc (<0.3 - 4.0)   | nc (<0.3 - 0.3)   | nc (<0.3 - 1.0)   | nc (<0.3 - 1.4)  |
| Cd    | all <0.1                               | all <0.2          | all <0.2          | all <0.2          | all <0.2         |
| Hg    | all <0.1                               | all <0.3          | all <0.3          | all <0.3          | all <0.3         |
| Ag    | all <0.1                               | all <0.1          | all <0.1          | all <0.1          | all <0.1         |
| Cr    | 59.7 (17.0 - 210)                      | 2.0 (1.1 - 5.0)   | nc (<0.3 - 0.9)   | nc (<0.3 - 0.6)   | nc (<0.3 - 0.8)  |
| Ni    | 74.2 (50.0 - 110)                      | 12.9 (2.7 - 33)   | all <0.6          | all <0.6          | all <0.6         |

**Table 4: Heavy metals in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)**

A study of this nature should also include the chemical analysis of biotic representatives, particularly key organisms of ecological and economic importance. This would facilitate the identification of critical contaminant pathways and permit a realistic assessment of any potential health risks to those who harvest any of the aquatic resources in this area for food.

#### *Subsurface Waters:*

Bacterial counts in soil pore waters down gradient of the Ordot Dump were surprisingly low considering the extremely high numbers present in leachate (Table 5). Even total coliform counts rarely exceeded 200 per 100 ml sample and were mostly around 2 or less per 100 ml sample.

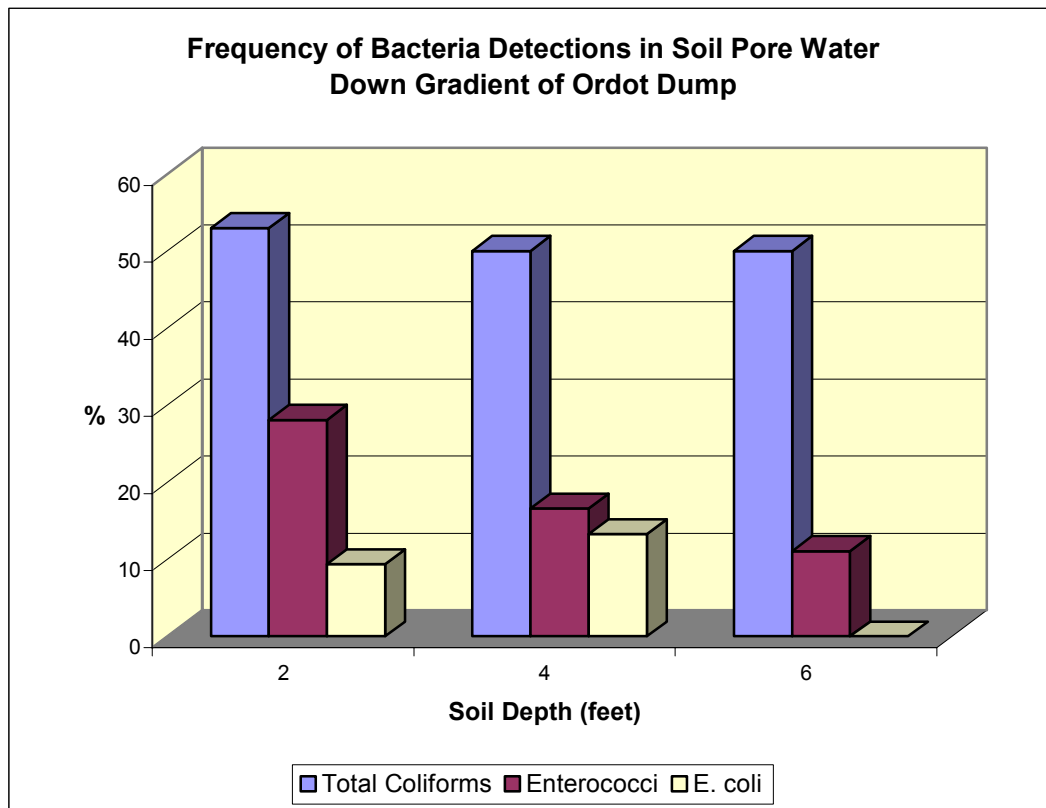
| Soil Depth (feet) | No. Samples | MPN Index/100 ml |                |                    |
|-------------------|-------------|------------------|----------------|--------------------|
|                   |             | Total Coliforms  | <i>E. coli</i> | <i>Enterococci</i> |
|                   |             | median (range)   | median (range) | median (range)     |
| 2                 | 32          | 2 (<2 - 4740)    | <2 (<2 - 20)   | <2 (<2 - 400)      |
| 4                 | 30          | 2 (<2 - 7016)    | <2 (<2 - 11)   | <2 (<2 - 31)       |
| 6                 | 36          | 2 (<2 - 4838)    | <2 (<2 - <10)  | <2 (<2 - 10)       |

**Table 5: Bacteria in soil pore waters down gradient from Ordot Dump (Oct. '02 – May '03)**

Both fecal indicator bacteria were rarely encountered at counts over 10 per 100 ml sample. Whether this is because bacteria in leachate from the dump are physically trapped in the overlying surface soil layers, or consumed by other soil microbes, or both, remains to be established. In any event, the data imply little to no subsurface movement of bacterial pathogens from the dump into the watershed.

It is interesting to note that the frequency with which *E. coli* and *Enterococci* were detected in soil pore water samples was depth related with the fewer detections at six feet than at two feet (Figure 2). In contrast, total coliforms were encountered in

approximately 50% of the samples collected at all three depths. It is also noteworthy that *Enterococci* were detected more often than *E. coli* at all soil depths.



**Figure 2: Frequency of bacteria detections in soil pore water down gradient from Ordot Dump (Oct. '02-May '03)**

Nutrient levels found in soil pore waters are summarized in Table 6. NO<sub>x</sub> enrichment was evident in the majority of samples from the shallower depths and occasionally at the deepest level. These findings highlight the mobility of the nitrate anion down through the soil profiles and could account, at least in part, for the relatively lush vegetation growing further down the watershed.

| Soil Depth (feet) | No. Samples | Nutrients (µg/l)    |                 |                  |
|-------------------|-------------|---------------------|-----------------|------------------|
|                   |             | NO <sub>x</sub> -N  | Ammonia-N       | Orthophosphate-P |
|                   |             | median (range)      | median (range)  | median (range)   |
| 2                 | 3           | 1,270 (339 - 8,124) | 5.8 (2.9 - 6.0) | 2.9 (1.0 - 16)   |
| 4                 | 5           | 5,990 (10 - 9,510)  | 32 (2.9 - 141)  | 18 (1.0 - 49)    |
| 6                 | 8           | 740 (5 - 35,455)    | 11 (4.3 - 35)   | 8.5 (1.0 - 59)   |

**Table 6: Nutrients in soil pore waters down gradient from Ordot Dump (Oct. '02 – May '03)**

Ammonia-N and orthophosphate-P levels were generally low and indicative of a fairly well aerated soil environment at all depths. Both nutrients showed some indication of depth-dependency with the highest levels occurring in samples from the deeper lysimeters. It seems unlikely that the low pore water bacteria counts noted above were related to a nutrient deficiency.

Heavy metal levels in the soil pore water samples have yet to be completed. However, the data thus far collected suggest all elements of interest are at, or close to, the limits of analytical detection with the possible exception of Al, Fe and Mn.

#### *Concluding Remarks and Recommendations:*

The results of this preliminary investigation show that leachate streams from the Ordot Dump transport substantial quantities of nitrogen, phosphorus and essential trace elements to the middle reaches of the Lonfit River. The extremely high fecal indicator bacteria content of the runoff also suggests that it could be a major source of human pathogens to the area. The biological impact of relatively high concentrations of certain potentially toxic heavy metals in the leachate requires further evaluation, particularly in the immediate downstream region of the watershed. Edible aquatic resources and potentially useful bioindicator species should be the primary focus of such studies. The subsurface movement of NO<sub>x</sub>, Al, Fe and Mn from the dump into the watershed is probably considerable. The latter metals could have a significantly negative impact on plant growth down gradient from the dump and warrant further investigation. Concentrations of PCBs, chlorinated pesticides (other than p-dichlorobenzene), PAHs, furans, dioxins, Hg, Cd, and the majority of organic solvents currently classified as priority pollutants by the USEPA, were undetectable in dump leachate and are not considered to be of any immediate importance. However, the continued and regular surveillance of all priority pollutants emanating from the dump is strongly recommended in order to identify any future quantitative and qualitative changes in contaminant concentrations.

#### **References**

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